Condition:

Write a note on gravitational red shift.

Solution and answer:

In astrophysics, **gravitational red shift** or **Einstein shift** is the process by which electromagnetic originating from a source that is in gravitational field is reduced in frequency, or red shifted, when observed in a region of a weaker gravitational field. This is as a direct result of Gravitational time dilation; frequency of the electromagnetic radiation is reduced in an area of a higher gravitational potential. There is a corresponding reduction in energy when electromagnetic radiation is red-shifted, as given by Planck's relation, due to the electromagnetic radiation propagating in opposition to the gravitational gradient. There also exists a corresponding blue shift when electromagnetic radiation propagates from an area of a weaker gravitational field to an area of a stronger gravitational field.

If applied to optical wavelengths, this manifests itself as a change in the color of visible light as the wavelength of the light is increased toward the red part of the light spectrum. Since frequency and wavelength are inversely proportional, this is equivalent to saying that the frequency of the light is reduced towards the red part of the light spectrum, giving this phenomenon the name red shift.

Red shift is often denoted with the dimensionless variable z, defined as the fractional change of the wavelength

$$z = \frac{\lambda_0 - \lambda_e}{\lambda_e}$$

Where λ_0 is the wavelength of the electromagnetic radiation (photon) as measured by the observer. λ_e is the wavelength of the electromagnetic (photon) when measured at the source of emission.

The gravitational red shift of a photon can be calculated in the framework of General Relativity (using the Schwarzschild metric) as

$$\lim_{r\to+\infty} z(r) = \frac{1}{\sqrt{1 - \frac{r_s}{R^*}}} - 1$$

with the Schwarzschild radius

$r_s = \frac{2GM}{c^2}$,

where G denotes Newton's gravitational constant, M the mass of the gravitating body, c the speed of light, and R^* the distance between the center of mass of the gravitating body and the point at which the photon is emitted. The red shift is not defined for photons emitted inside the Schwarzschild radius, the distance from the body where the escape velocity is greater than the speed of light. Therefore this formula only applies when R^* is at least as large as r_s. When the photon is emitted at a distance equal to the Schwarzschild radius, the redshift will be infinitely large. When the photon is emitted at an infinitely large distance, there is no red shift.

In the Newtonian limit, i.e. when R^* is sufficiently large compared to the Schwarzschild radius r_s, the redshift can be approximated by a binomial expansion to become

$\lim_{r\to+\infty} z_{approx}(r) = \frac{1}{2}\frac{r_s}{R^*} = \frac{CM}{c^2R^*}$.